Cooking characteristics and consumer acceptability of bio- fortified beans (*Phaseolus vulgaris L*.)





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1. **INTRODUCTION**

Beans (*Phaseolus vulgaris* L.) are grain legumes that belong to the family of Leguminosae. Beans are important legume crops for resource poor small-scale farmers in Malawi and it is mainly used for human consumption worldwide (Mkanda, 2007). Beans can either be grown as a sole crop especially by commercial farmers or intercropped with maize, a common practice among most subsistent farmers in Africa (Mkanda, 2007). Beans provide proteins and energy in the diet for many people both in rural and urban areas and that beans are major sources of dietary protein especially in Kenya, Tanzania, Malawi, Uganda and Zambia (AGSI/FAO, 2004). Common beans also provide calcium, magnesium, vitamin B, iron and zinc which are essential for immune in human bodies. Beans are mainly cultivated by small scale farmers, hence it provides money after selling (CIAT, ICRISAT and IITA, 2013).

Cooking quality in legumes include cooking time, splitting during cooking, texture and other sensory attributes (Mwangwela, Waniska and Minnaar ,2006) and cooking time is an essential characteristic commonly used to determine quality of a good legume (Yeung,2007). There is variation in bean varieties worldwide and the variation is due to physicochemical and sensory properties (AGSI/FAO, 2004). However, there are some challenges concerning beans utilization and consumption of which long cooking time is one of them. Beans with long cooking time lead to high energy expenses especially in low income communities.

Studies conducted by (Scott and Maiden1998); Ngwira and Mwangwela (2002) and (Mtimuni*,* Ngwira,Kaponya and Cusack,(1992) showed that consumers of beans in Malawi like fast cooking beans as the most important characteristics in selecting bean varieties for production and consumption. Plant breeders mainly have focused on producing beans with high pest and disease resistant’s and high yield (Chirwa and Rubyogo, 2014), but the cooking characterictics of newly bio- fortified beans have not been adequately studied. Therefore this study aimed at determining the cooking characteristics of three bio-fortified beans comparing to local variety.

**1.1Main objectives**

To determine cooking characteristics of bio- fortified beans

**1.1.1Specific objectives of the study**

* To determine the moisture content of bio-fortified beans
* To determine the cooking time of bio- fortified beans
* To determine the splitting percentage of bio- fortified beans
* To determine water absorption of bio-fortified beans
* To determine the soluble solid loss (broth thickness ) of bio-fortified beans
* To access consumer acceptability of bio-fortified beans compared to local variety

1. **METHODOLOGY**

**2.1Study area**

Analysis of cooking characterictics was done at Lilongwe University Agriculture and Natural Resources specifically in Nutrition and Food Science Laboratory.

**2.2 Sources of raw materials**

Four varieties namely NUA 45, NUA 59, NUA35 and Napilira were collected from Chitedze Research Station (ICRISAT) and these beans were grown in 2018 to 2019 growing season.

**2.3Sample handling, processing and storage**

Beans were sorted to remove stones, broken and rotten seeds and defective grains, followed by packing in plastic pails and then stored in deep freezer ready for analysis.

**2.4 Sample analysis**

All analysis were done in four varieties and whole dry beans was used in this study. All the analysis were replicated five times inoder to be accuracy and to be more precise.

**2.4.1 Moisture content of beans**

Moisture content of bean seeds was determined according to method of Machinjili, (2018). Thirty grams of bean seeds were weighed (M0) into pre dried moisture tins (1h, 103oc) that were cooled in a desiccator. The samples were dried for 72 hours in a hot air oven at 103 oc. the dried samples were cooled in desiccator and weighed (M1) moisture content was calculated as follows:

Moisture (%) = M0-M1x100

M0

**2.4.2Determination of water absorption during soaking of beans at room temperature**

The water absorption of bean seeds during soaking were determined by a modified method of Agbo, Hosfield, Uebersax and Kimparens (1987). Ten grams of bean seeds were placed in 100 ml Erlenmeyer flasks containing 50 ml deionised water. The Erlenmeyer flasks were placed in an incubator at 22oC for 1, 2, 3, 4, 5, and 6 hours. At each interval the excess water were drained using metal sieve (2.5mm) and beans were then blotted dry with absorbent paper to remove excess water and afterwards weighed. Five replicates each done in duplicate were used. The mean of gain in weight of soaked samples were expressed as a g water kg-1 beans corresponding to water absorbed (WAS) according to the following formula:

WAS= weight of sample after soaking- weight of the sample before soaking

Weight of the sample before soaking

**2.4.3Determination of water absorption during cooking of beans**

The amount of water absorbed during cooking was determined using Cenkowski and Sosulski (1997) method. For each variety of beans, approximately 10g of beans was placed in 100 ml Erlenmeyer flasks containing 50 ml deionised water. The Erlenmeyer flasks were placed in a heavy aluminium pan containing 3000 ml of deionised water. The pan was tightly covered and brought to boil allowing 5min for heating up. The beans were cooked at 30, 60, 90, 120, 150, 180 210 and 240min. After cooking, two sample flasks per beans variety were removed and excess water was drained using metal sieve (2.5mm). The beans were cooled to room temperature for 1 hour, blotted dry with absorbent paper to remove excess water and weighed. The gain in weight (g) was expressed as a g water kg-1 beans.

WAC= Weight of the sample after cooking – weight of sample before cooking

Weight of the sample before cooking

**2.4.4Determination of splitting during cooking of beans**

Splitting of seeds during cooking was determined according to method of Van Buren, Bourne, Downing, Quele, Chise and Comstock (1996). The bean seeds with split seed coats and cotyledons were counted as splits. The degree was calculated as follows:

Number of split seeds X 100

Number of whole seeds

**2.4.5 Determination of cooking time of beans**

Cooking time was determined according to Mattson method that was later modified by Jackson and Variano Martson (1981) using Mattson cooking device. The apparatus has a cooking rack (Mattson cooker) with 25 rods 49.8g each and 25 cylindrical holes (nine millimetre diameter) where seeds were placed. The piercing tip of each rod was placed in contact with the surface of the seed. The Mattson cooker was placed into a stainless steel pot containing about 3000ml of boiling deionised water. When the bean seed was sufficiently tender, the piercing tip penetrated the cooked seed and the rods dropped through the hole in the saddle (Jackson and Variano Marston 1981). The cooking time was recorded when 20 rods (80%) had fallen through the cooked seeds.

**2.4.6 Determination of total soluble solids (broth thickness) of beans**

Broth thickness was measured by determining the total soluble solid in the broth by oven drying the broth. The crucibles were dried in oven for two hours at 80oC and allowed to cool to room temperature. The dry crucibles were weighed and the weights were recorded as ‘empty crucible’, 15 ml of broth was transferred into the weighed crucible and weighed. The weight was recorded as ‘crucible + broth’. The crucibles with broth were placed in a drying oven set at 105 ºC for 16 hours for sample to dry. The crucibles with dry broth were removed from oven with tongs and placed into desiccators to cool. The dry crucibles were then weighed with solids remaining from broth. The weight was recorded as ‘crucible + dry broth.

**2.5 Sensory evaluation using Check All that Applies (CATA) of Bio-fortified Beans**

Sensory evaluation of bio-fortified beans was conducted in Linthipe EPA in the following villages: Mbidzi, Nkhanganya and Nkuwazi. Purposive sampling was used to select farmers who grow bio fortified beans who are beneficiary of Africa Rising project. In each village 50 panelists were selected purposively making it to 150 panelist’s participation in this study. Four bean varieties (NUA 59, NUA 59, NUA 35 and Napilira were tested by each panelist. One sample was presented at a time. CATA tool was used in this sensory., Panelists were presented with all attributes associated with dry beans and were asked to choose which attribute applies , after that 5 point hedonic scale was used to assess their liking level, 1 representing extremely dislike, and 5 representing extremely like.. Lastly, panelists were asked to rank the bean samples from number one up to number four in their preference.

**2.5.1Sample preparation during sensory evaluation of beans**

Beans (500 g) of each variety were cooked using firewood in an open space. Beans were cooked for 3 hours. All the bean varieties were cooked at same time, same amount of water and using firewood. Two grams of salt was added 15 minutes before end time of cooking. Each panelist was given 20 g of each bean variety served using transparent bowls and spoons, with blind codes of3 digits. Bean samples were placed on white tray with a glass of water for cleansing the mouth before and in between tasting of each sample. Samples were served in a block design.

**2.6 Data analysis**

Data were entered in Microsoft excel and then analysed GenStat version 15. Analysis of variance was determined for all parameters. Significant means were separated using Least Significant Difference (LSD) at P <0.05 level of confidence. Data analysis was done in XLSTAT (ver 19.01; Addinsoft, New York). Data for hedonic one-way (ANOVA) was used and Tukey's honestly signiﬁcant difference (HSD) test was used for means separation. Cochran's Q test followed by McNemar's (Bonferroni) method for pairwise comparisons was used to analyze CATA data. The mean impact was analyzed to assess the effect of the CATA responses on overall liking mean scores of the samples. Principal Component Analysis (PCA) was used in order to determine the attributes that are associated with bean varieties

1. **RESULTS AND DISCUSSION**

**3.1 Cooking characteristics of biofortified beans**

**3.1.2 Moisture content of beans**

Moisture content was high in NUA59 bean variety, followed by NUA 45 and then Napilira. NUA 35 had the lowest moisture content (7.72%). The results obtained showed that there was no significant difference in moisture content at p value 0.05 as shown in table 1 below.

**Table 1, Moisture content of dry beans**

|  |  |
| --- | --- |
| Bean variety | Moisture (%) |
| NUA59 | 8.30a ± 0.74 |
| NUA45 | 8.19a ± 0.29 |
| Napilira | 7.84a ± 0.19 |
| NUA35 | 7.72a ± 2.03 |
| P value | 0.978 |

*Values followed by different superscripts in one column indicate a significance difference (P<0.05) Mean ± Standard error*

Altuntas and Demirtola (2010) reported moisture percentage of whole dry black-eyed pea, pea and kidney beans to be 8.21%, 8.20%, and 5.66% respectively. Moisture content percentage found in this study is within the range of typical dry legumes, which is 5% to 16 %. Low moisture content suggests relatively long shelf life of commodities (Ade- Omowayele, Tucker and Smetanska, 2015).

**3.1.2Water absorption of beans during soaking**

There was increase in amount of water absorption per kilogram of Napilira, NUA 45, NUA 59 and NUA 35 with increasing in soaking time as shown in figure 1. NUA35 (608 g of water/kg) showed to absorb more water as compared to other varieties. Napilira (513 g of water/kg) had lowest water absorption capacity.

Error bars that do not overlap indicates significant difference (P< 0.05)

**Figure 1: Graph showing water absorption during 6 hours of soaking beans**

Chewere, (2010) reported that hydration capacity of 10 varieties of beans to range from 955 to 1245 after 24 hours of soaking and also Kang’ombe, (2016) found the water absorption of dry bambara groundnuts ranged from 9.8 to 529 g of kg/water. Water absorption of beans reported in this current study are slightly higher as compared to what Kang’ombe (2016) documented. Water absorption of legumes is a measure of gross water uptake by seeds during soaking and is influenced by the integrity of the seed coat (Urga *et al*, 2006). Thick seed coats reduced water absorption during the first six hours of soaking. Agbo et al. (1987) also reported that the thickness of the seed coat palisade layer caused slow hydration rates, due to the barrier created by the sheet of cells, appearing like bundles, to the fast movement of water through the cotyledon cells. High hilum length and open and large opening of the micropyle have been documented to increase rapid water absorption during soaking (Sefa-Dedeh & Stanley, 1979b; Sefa-Dedeh & Stanley, 1979c).

**3.1.3 Water absorption during cooking of beans**

There was an increase in water absorption with increased cooking time as shown in figure 2 below. NUA 59 had highest water absorption and NUA45 having the lowest water absorption at cooking of 240 minutes. There were no significant differences in water absorption during cooking among the 4 varieties at p< 0.05.

Error bars that do not overlap indicates significant difference (P< 0.05)

**Figure 2: Graph showing water absorption during cooking of beans for 4 hours**

During the first 30minutes, there was rapid initial water uptake observed in both varieties. The rapid rate was due to filling of capillaries on the surface of seedcoat at hilum (Hsu *et al.,* 1983). NUA 59 had high uptake of water during cooking and this might be due to its thick seed coat comparing to other varieties. At 150 minutes there was decrease in water absorption this shows that NUA 35, NUA 45, NUA59 and Napilira reached a point full hydration of gelatinized starch.

**3.1.4 Cooking time of beans**

Significant differences were observed (p0.017) in cooking time of beans. NUA 35 showed to take more time to cook (101 minutes) while NUA 45 and NUA 59 took less time to cook 81 and 87 respectively. Chewere,(2010) reported cooking time of beans to range from 60 to 89 minutes of BCMV B2 Kalima, Nasaka, BCMV B4 and BCD/O 19. Mkanda, (2007) studied six bean varieties grown in different locations, cooking time varied from 42.4 to 97.8 minutes. The findings of present study are higher as compared to other studies the reason might be to different varieties, physicochemical properties of the cotyledons and the skin of the beans (Barros and Prudencio, 2016). Cooking time has been defined as the time required for beans to reach the cooked texture that is considered acceptable to consumers (Moscoso, Bourne & Hood, 1984). Cooking time is more ideal because it is close to the texture that is preferred by consumers (Proctor and Watts, 1987). Cooking time in beans ranges from 45 minutes to 230 minutes depending on the variety, cooking medium and method (Mwangwela 2000, Bean/Cowpea CRSP, 1995, Shellie Dessert and Hosfield, 1990). Consumers prefer beans that cook fast to those that are long cooking because it saves them on energy costs and time for preparation of meals. Well-cooked beans have a soft texture and most consumers prefer such beans because they are easy to chew. Hence NUA 45 and NUA 59 will be ideal bean varieties to serve energy and time.

*Different superscripts shows significant differences p<0.05*

**Figure 3, Graph showing cooking time of beans**

**3.1.5 Splitting percentage of beans**

There were significant differences in splitting percentage of beans p0.004. NUA59 recorded highest value of 54.4% while NUA35 recorded the lowest (27.0%). NUA59, NUA45 and Napilira were not significant to each other while NUA 35 was different to the three varieties of beans. Chewere, (2010) found similar splitting percentages of seed coat and cotyledon (20 to 53.1 %) of beans. Splitting percent during cooking is affected by the seed coat thickness, seed density, texture of cooked beans and calcium levels available.

*Different superscripts shows significant differences p<0.05*

**Figure 4, Splitting % of beans**

Splitting is an indication of cotyledon softening, it is not always an indication that the seed is cooked (Taiwo 1998). Penicela, (2010) observed that cowpeas with thick seed coats have higher percentage of splitting compared to cowpeas with thin seed coats. Penicela (2010), reported that splitting in legume seeds is associated with high water absorption and rate of splitting increases with increased cooking time. These findings of this study are contrary to what is reported with Kang’ombe, (2016) that increase in water absorption during soaking and cooking and this resulted in increasing splitting percentage of bambara groundnuts. NUA35 bean variety in this study showed to absorb more water during soaking and cooking, but it showed less splitting. NUA 59, NUA45 and Napilira showed to have high percentage of splitting with less water absorption. The differences might be due genetic makeup of NUA35 which limit the splitting of beans of this variety. NUA59, NUA45 and Napilira will be ideal in making chipere as compared to NUA35.

**3.1. 6 Soluble solid loss (broth thickness) during cooking of beans**

The broth thickness varied among bean varieties. Bean variety affected broth thickness (p <0.001). Soluble solid loss of this study ranged from 4.87 to 11.83%. NUA59 had high soluble solid (11.83 %) and Napilira was the lowest (4.87%). Yeung, (2007) found that soluble loss of cowpea ranged from 7 to 14 %. The findings of this study are lower as compared to what Yeung, (2007) reported.

**Figure 5, soluble solid loss (broth thickness) during cooking of beans**

The thicker the broth in NUA59 variety might be due to higher amount of amylose that leached out and stayed dispersed in the cooking water (Chewere, 2010). Broth thickness of beans happens due to leaching out of the soluble solids such as protein and starch from the seed. These soluble solids may form a gel that could thicken the water used during cooking of beans. Wu, (2002) reported that the high splitting % of beans during cooking results into thick broth formed. Findings of Wu, (2002) agrees with the present finding. NUA59 was high in splitting percentage and this resulted into more soluble loss, therefore making the broth to be thick. But this theory did not work for NU35, NUA45 and Napilira. NUA35 had low splitting percentage, resulted into thick broth as compared NUA45 and Napilira which showed to have high splitting percentage.

**3.2 Consumer acceptability of beans**

**3.2.1 Demographic Information**

The majority of respondents were females (84%), because Africa Rising has few men farmers than females. A high percentage of respondents were in age range of 40-50 years. Most of the participants were married (72 %). Highest level of education attended by most farmers was primary education. Farming was main occupation (93.3 %) to find money for their basic needs. The annual income of majority was in range of 50,000.00 to 90,000.00 Malawi Kwacha after selling their field harvest (32.7%). Those with total income above 100,000 Malawi Kwacha were 26.7 %.

**Table 2, Demographic characteristics of panelist**

|  |  |  |
| --- | --- | --- |
| **Characteristic** | **Frequency** | **Percentage** |
| **Sex** |  |  |
| Male | 24 | 16 |
| Female | 126 | 84 |
| **Age** |  |  |
| 20-30 | 28 | 18.7 |
| 31-39 | 37 | 24.7 |
| 40-50 | 40 | 26.7 |
| 51-59 | 16 | 10.7 |
| **above 60** | 24 | 16.7 |
| **Marital status** |  |  |
| Married | 108 | 72 |
| Divorced | 15 | 10 |
| Single | 1 | 0.67 |
| Widow/widower | 26 | 17.33 |
| **Education level** |  |  |
| Primary | 106 | 70.67 |
| Secondary | 8 | 5.33 |
| Adult literacy | 1 | 0.67 |
| None | 35 | 23.33 |
| **Occupation** |  |  |
| Farmer | 140 | 93.33 |
| Business | 1 | 0.67 |
| Farmer and casual labour | 2 | 1.33 |
| Farmer and business | 5 | 3.33 |
| Live with parents | 1 | 0.67 |
| Employed officer | 1 | 0.67 |
| **annual income** |  |  |
| 10,000 - 20,000 | 33 | 22 |
| 21,000-29,000 | 5 | 3.33 |
| 30,000-40,000 | 18 | 12 |
| 41,000 - 49,000 | 6 | 4 |
| 50,000 - 99,000 | 49 | 32.67 |
| 100,000 above | 37 | 24.67 |
| **Don't know** | 2 | 1.3 |

**3.2.2 Consumption Frequency of biofortified beans**

Consumption frequency data of biofortified beans was collected. All the respondents in this study consume common beans. A higher percentage (82 %) of respondents have ever consume biofortified beans while 18 % have not yet consumed bio-fortified beans because it was their first year to grow bio-fortified beans. On frequency of consumption, those that have access to biofortified beans majority would consume beans at least once a week. Others consumed more than once a week while others consumed even once month. A higher percentage of respondents had consumed fortified beans in previous month (27.3 %) while 22.7 % of respondents had consumed fortified beans in a previous week. Taste was the most attribute liked on bio-fortified beans (38 %), seconded by smell (12%). Others liked colour, smell and taste (10 %) while others liked smell and taste, others colour and taste and others liked colour only. Other attributes liked was that of easy to cook. This is the one major factor that respondents consider when purchasing beans, to save resources such as firewood. Other respondents consider colour of beans (20 %), while others consider of colour and easy to cook (25 %). A fewer percentage (10 %) consider grain size, colour and easy to cook bean characteristics when purchasing beans for consumption. The consumption patterns showed that the respondents were already familiar with bio- fortified beans.

**Table 3, Consumption patterns of bio-fortified beans**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Category** | **Frequency** | **Percentage** |
| Consumption frequency of Bio-fortified beans | once a week | 46 | 30.7 |
| Once a month | 29 | 19.3 |
| N/A | 27 | 18.0 |
| others | 48 | 32.0 |
| Last time consumed Bio-fortified beans | A week ago | 34 | 22.7 |
| A month ago | 41 | 27.3 |
| More than six months ago | 26 | 17.3 |
| More than a year | 6 | 4.0 |
| Others | 16 | 10.7 |
| N/A | 27 | 18.0 |
| Attributes liked on Bio-fortified beans | Color | 9 | 6.0 |
| Smell | 19 | 12.7 |
| Taste | 58 | 38.7 |
| color, smell and taste | 15 | 10.0 |
| Color and Smell | 3 | 2.0 |
| Color and Taste | 4 | 2.7 |
| Smell and Taste | 14 | 9.3 |
| N/A | 27 | 18.0 |
| Factors considered when purchasing beans | Grain size | 7 | 4.7 |
| Color | 30 | 20.0 |
| Easy to cook | 43 | 28.7 |
| Grain size and Color | 6 | 4.0 |
| Grain size and easy to cook | 6 | 4.0 |
| Color and easy to cook | 38 | 25.3 |
| Grain size, color and easy to cook | 16 | 10.7 |

**3.3.3 Consumer acceptability using CATA methodology**

**3.3.3.1 Appearance of cooked beans**

Colour was not significant in the four varieties p (0.993). Napilira and NUA 59 appeared to be more brownish compared to NUA 35 and NUA 45. The brown colour in bean seed coat is associated with availability of phenolic compounds and flavonoids (Machinjili, 2018), these attribute to dark colour of beans when cooked. NUA 59 was rated to be shinier while NUA 35 was dull in appearance. Splitting, size, broth and seed coat attributes were significantly different among the 4 varieties tasted by consumers

The greater proportion of panelist indicated NUA 59 bean variety as shiny, big, splitted, peeled seed coat and viscous broth as compared to other bean varieties. These findings agrees with the cooking characterictics which were obtained earlier during laboratory analysis as shown in figure 4 and 5 above. NUA 59 had high splitting percentage and thick broth while NUA 35 was lowest in splitting percentage, but the broth was thick as compared to NUA 45 and Napilira. NUA 35 was second in broth viscosity after NUA 59 was rated to be thick by panelist as it can be seen in table 4 below and this also agrees with data from laboratory which showed NUA 35 broth to be thicker as compared to NUA 45 and Napilira. According to Rios et al. (2002), consumers prefer lighter colored beans, because they relate darker color to old, hard beans that require more time to cook, generating increased energy expenditure. Beans with more number of splits is associated with peeled seed coats (Mkanda, 2007), this relationship is observed with NUA 59 it was splitted and it had peeled seed coats (table 4). The presence of minerals in bean seed coat affects the splitting during cooking (Wu *et al.,* 2005). The less splits in NUA 35 bean variety might be attributed to high concentrations of Calcium, iron and Sodium in seed coat.

**Table 4, Cochran's Q test for each attribute assessed**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attributes | NUA 35 | NUA45 | NAPILIRA | NUA 59 | p-values |
| Brownish/Red | 0.643a | 0.643a | 0.652a | 0.652a | 0.993 |
| Shiny | 0.317a | 0.313a | 0.370ab | 0.439b | 0.009 |
| Dull | 0.322ab | 0.335b | 0.278ab | 0.204a | 0.008 |
| Splitted | 0.109a | 0.361b | 0.404bc | 0.522c | 0.000 |
| Not Splitted | 0.522c | 0.270b | 0.230b | 0.130a | 0.000 |
| Big | 0.287a | 0.300a | 0.361a | 0.622b | 0.000 |
| Medium | 0.030a | 0.013a | 0.026a | 0a | 0.05 |
| Small | 0.322b | 0.304b | 0.265b | 0.022a | 0.000 |
| Peeled seed coat | 0.039a | 0.139b | 0.217b | 0.352c | 0.000 |
| Unpeeled seedcoat | 0.600c | 0.50bc | 0.430b | 0.287a | 0.000 |
| Liquidity broth | 0.387b | 0.570c | 0.517c | 0.026a | 0.000 |
| Viscous broth | 0.248b | 0.074a | 0.122a | 0.617c | 0.000 |
| Cooked bean Aroma | 0.270a | 0.326ab | 0.413b | 0.626 c | 0.000 |
| Raw bean Aroma | 0.370c | 0.317bc | 0.230b | 0.013a | 0.000 |
| Burnt Aroma | 0.030a | 0.026a | 0.013a | 0.013a | 0.427 |
| Metallic Aroma | 0.035a | 0.035a | 0.052a | 0.013a | 0.11 |
| Sweet taste | 0.117a | 0.222bc | 0.148ab | 0.283 c | 0.00 |
| Bitterness taste | 0.030a | 0.004a | 0.009a | 0a | 0.009 |
| Salty taste | 0.413a | 0.417a | 0.461a | 0.461a | 0.509 |
| Old Grain taste | 0.417c | 0.330bc | 0.300b | 0.178a | 0.00 |
| New Grain taste | 0.222a | 0.300ab | 0.343bc | 0.461c | 0.00 |
| Burnt taste | 0.048a | 0.022a | 0.026a | 0.030a | 0.32 |
| Cooked Bean Taste | 0.274a | 0.330ab | 0.439b | 0.626c | 0.00 |
| Raw bean taste | 0.361c | 0.300bc | 0.209b | 0.009a | 0.00 |
| Metallic Feeling/taste | 0.074b | 0.057ab | 0.052ab | 0.013a | 0.013 |
| Soft | 0.226a | 0.326ab | 0.452b | 0.639c | 0.000 |
| Hard | 0.422c | 0.330c | 0.196b | 0.013a | 0.000 |
| Tough | 0.483c | 0.391bc | 0.330b | 0.087a | 0.000 |
| Fragile | 0.148a | 0.222ab | 0.317b | 0.561c | 0.000 |
| Mushy | 0.078a | 0.226b | 0.317b | 0.578c | 0.000 |
| Stiff | 0.522c | 0.387b | 0.291b | 0.065a | 0.000 |
| Grainy | 0.357c | 0.243b | 0.183b | 0.026a | 0.000 |
| Smooth | 0.291a | 0.400ab | 0.470b | 0.626c | 0.000 |
| Juicy | 0.113a | 0.243b | 0.304b | 0.474c | 0.000 |
| Dry | 0.435c | 0.322b | 0.248b | 0.104a | 0.000 |

**3.3.3.2 Aroma of cooked beans**

Cooked bean and raw bean aroma were significant p (0.05) while burnt and metallic aroma were not different among the bean varieties shown in Table 4. Higher proportional of panelists in this study rated NUA 59 to be associated with cooked bean aroma (0.626) while NUA 35 was rated to have aroma of uncooked beans (0.370). Cooked bean aroma is due to strecker degradation which is a chemical reaction and this process involves amino acids reacting with a carbonyl 1 compound to form ketones, aldehyde and other volatile compounds (Rizzi*,* 2008). The more the amino acids and carbonyl groups in a bean variety, more volatile compounds are produced resulting in higher intensity of aroma (Chewere, 2010).

**3.3.3.3 Taste attribute of cooked beans**

There was significant differences in sweet, bitter, grain (new and old), cooked bean, raw cooked bean and metallic taste. Salty and burnt taste were not different among the varieties. NUA 59 exhibited high in sweetness, new grain taste and cooked bean taste while NUA 35 had bitter taste, old grain taste, raw bean taste and metallic taste (table 4 above). Sucrose is the major sugar in legumes unlike cereals (Ihehoronye, 1985). Phenolic compounds and mineral content affect the taste. The higher mineral content/phenolic compound of beans (e.g iron) cause the consumers to notice the beans to be bitter and this might be the case of NUA 35 which reported to be bitter. Mkanda, (2007) also reported that thermal heat treatment impacts starch gelatinization and complex sugars break down to simple sugars such as glucose and fructose bringing about desirable flavours such as the sweet taste of cooked beans.

**3.3.3.4 Texture attribute of cooked beans**

All texture attributes were significantly different p (0.000) among the varieties used in this study. Panelist categorized NUA 59 bean variety to be soft, mushy, fragile seed coat, smooth and juicy while NUA 35 was characterized as hard, tough seed coat, stiff, grainy and dry attributes. If the cell walls of the beans are rigid, swelling and dispersion of starch during cooking is inhibited rendering the cooked beans to be hard in texture (Wang et al., 2003). During cooking, water uptake could also be affected by differences in the rate of starch gelatinization, nature and amounts of non-starch constituents (such as protein) that may cause a barrier to swelling of starch granules (Deshpande & Cheryan, 1986) resulting into hard textured cooked beans. Seed coat residues in the mouth were experienced in the hard textured beans, which could be attributed to tougher seed coats that take long to disintegrate during chewing.

**Table 5, Consumer liking of bean varieties using 5 point hedonic scale**

|  |  |
| --- | --- |
| Bean variety | Liking |
| NUA 59 | 4.913 a |
| Napilira | 3.993 b |
| NUA 45 | 3.696 b |
| NUA 35 | 3.034 c |
| P value | < 0.0001 |

**3.3.3.5 Consumer liking of cooked bean varieties**

Consumers/panelists were asked to rate the liking of each and every bean tasted using five hedonic scale. The majority liked NUA 59 followed by Napilira and lastly the least preferred was NUA 35. Mkanda (2007) reported that varieties with the most split beans, soft and mushy were more acceptable by consumers, hence the high liking of NUA 59 by consumers as compared to other bean varieties. The results of this study are in agreement with Mkanda (2007) who assessed the relationship of consumer preferences to sensory and physicochemical properties of dry beans which found that beans rated low in liking was a result of hard texture and appearance . The bean varieties that were described by the descriptive sensory panel as sweet, having cooked bean flavours, and soft textures (Jenny-MP, Kranskop and PAN 148) were the ones preferred by consumers. On the contrary, those varieties that were described as hard in texture, split and having raw bean flavours, bitter, soapy and metallic feeling in the mouth (Mkuzi-MP, AC Calmont-MP and FS PAN 150-MP and Jenny-FS) were the least preferred.

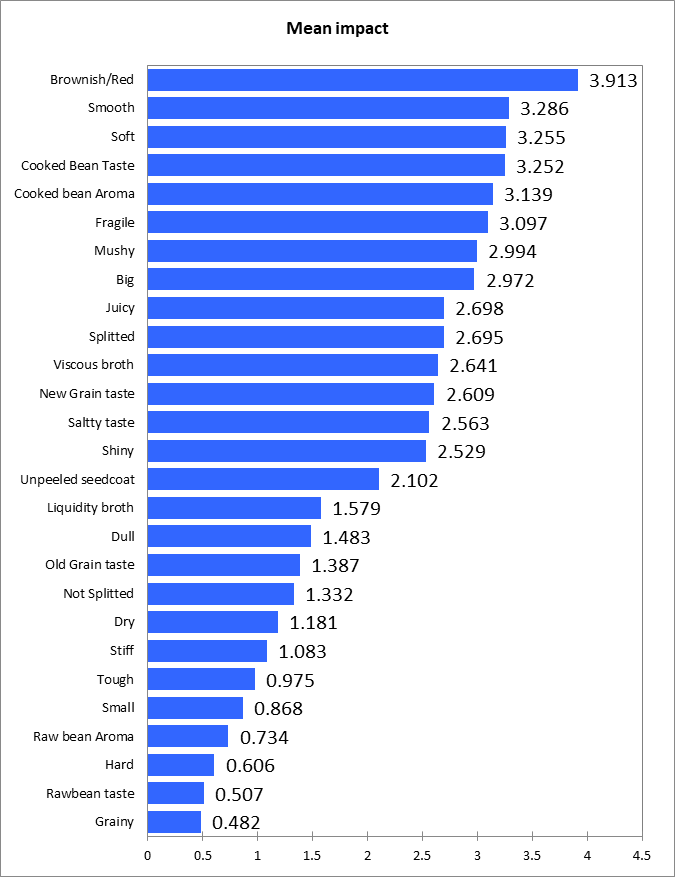
Figure 6, Score plot showing relatedness of bean samples rating to sensory characteristics.

**Note**: 789: NUA 59, 225: NUA 45,520: Napilira, 130: NUA 35

The symmetric plot shown in Figure 6 is showing association of products and attributes and the closeness of the samples. The first two principal components explained 98.85% of variation in bean samples. There was high variance in PC1 and PC2 which showed that there was high systematic variation within the data. This shows that panelist discriminated well between the samples. For PCA to be significant, at least 50 % cumulative variance has to be explained (Arvanitoyannis, Mavromatis, Rodiatis and Goulas*,* 2007). NUA 59 and NUA 35 was observed with no closeness in their sensory attributes while NUA 45 and Napilira were close (they are associated with same sensory attributes). The PCA explain how panelist rated each sample and its attributes related to particular sample. PC1 accounted for 88.95 % which shows NUA 59 is associated with viscous broth, big, shiny, softness and cooked bean aroma, sweetness splitted and peeled seed coat. PC2 explains the difference (9.89) in NUA 35, NUA 45 and Napilira. NUA 35 associated with bitterness, hardness, not splitted, burnt aroma, metallic taste, grainy and raw cooked bean aroma/taste. Figure 7 is showing the association of liking and attributes.

**Figure 7, Association of Liking and Attributes**

In this study it showed that bean variety which are liked are associated with the following attributes: peeled seed coat, splitted , mushy, big, soft, fragile seed coat cooked bean aroma/taste, viscous broth, new grain taste, salty brownish, in this case NUA 59 was associated with these attributes, hence it was highly liked/preferred by consumers. Figure 8 below show mean impact of significant attributes on liking. The colour of bean variety (brownish /red) had highest mean impact and grainy attribute had the lowest mean impact. This means that beans with brown colour will be more liked than beans which have grains (more grains remaining in month after chewing). These attributes need to be considered when breeding for new variety of beans.



**Figure 8,** **Mean impact of significant attributes on liking of beans**

**4.0 CONCLUSION**

Moisture content, water absorption during soaking and during cooking did not differ in terms of variety. Cooking time, splitting percentage and soluble solid loss varied with bean variety. NUA45, NUA59 and Napilira had short cooking time and high splitting percentage and this indicates good texture and taste quality. NUA35 should be soaked first before cooking to reduce cooking time, hence serving energy and time. NUA 59 was most preferred variety among the varieties due to its softness, cooked bean aroma, cooked bean taste, splitted, shiny, mushy and juiciness. Napilira was second followed by NUA 45 and NUA 35 was the least preferred.

**5.0 REFERENCES**

Ade- Omowayele, B.I. O., Tucker, G.A. and Smetanska. I., (2015). National potential of nine undeexploited legumes in southwest. *Nigeria International Food Research Journal* 22:798-806: http//www.ifrj.upm.edu.my/22%20(02)%202015(48).pdf

Agbo, G.N., Hosfield, G.L., Uebersax, M.A. and Klomparens, K. (1987). Seed microstructure and its relationship to water uptake in isogenic lines and a cultivar of dry beans (Phaseolus vulgaris L.). Food Microstructure 6, 91-102.

Agbo, G.N., Hosfield, G.L., Uebersax, M.A., and Klomparens, K., (1987). Seed microstructure and its relationship to water uptake in isogenic lines and cultivars of dry beans (*Phaseolus Vulgaris L*). *Food Microstructure* 6: 91-102. DOI: 10.1.1.1016.6567.

Agro-industries and post-harvest management service (agsi) /food and agriculture organization (FAO), 2004. Chapter IV. Phaseolus beans: Post-harvest operations; http://www.fao.org/inpho/content/compend/text/ch04.htm.

Altuntas., E. and Demirtola., H. (2010). Effect of moisture content on physical properties of some grain legume seeds New Zealand Journal of Crop and Horticultural Science;DOI: 10.1080/01140670709510210.

Cenkowski, S. and Solulski, F.W. (1997). Physical and cooking properties of micronized lentils. *Journal of Food Process Engineering* 20: 249-264. DOI: 10.1111/j1745-4530.1997.tb00421.x.

Chewere, Y. (2010). *Consumer acceptance of beans (Phaseolus vulgaris L) screened using Rapid method*. MSc thesis. University of Malawi. Bunda College of Agriculture, Lilongwe, Malawi.

Chirwa, R. and Rubyo ,J.C. (2004). Demand-led Bean Varieties: the case of SUG131 in Malawi. <file:///C:/Users/USER/Downloads/rc_sug131demandled_variety_development_2014.pdf>

CIAT, ICRISAT and IITA. (2013). A BULLETIN OF THE TROPICAL LEGUMES II PROJECT <file:///C:/Users/USER/Documents/bamabara%20review/November-2013.pdf>

Jackson, G.M and Variano Marston, E., (1981). Hard to cook phenomenon in Beans: Effects of accelerated storage on water absorption and cooking time *Journal of Food science* 46: 799-803. DOI: 10.1111/j.1365-2621.1981.tb15351.x.

Machinjili. T.T. (2018). Proximate composition, cooking and sensory characteristics of different varieties of pigeon peas. Unpublished MSC thesis

Mkanda, (2007). Relating consumer preferences to sensory and physicochemical properties of dry beans (Phaseolus Vulgaris). MSc thesis. University of Pretoria, South Africa.

Moscoso, W., Bourne, M. C., and Hood L. F., (1984). Relationship between the hard-tocook phenomenon in red kidney beans and water absorption, puncture force, pectin, phytic acid and minerals. Journal of Food Science, 49: 1577-1583

Mtimuni, B. M., Ngwira M. M., Kaponya D. M., and Cusack G. W., (1992). Utilisation of legume in the home sub-project. Annual report. University of Malawi, Bunda College, Lilongwe, Malawi.

Mwangwela A. M., Waniska R. D. and Minnaar A (2006). Hydrothermal treatments of two cowpea (Vigna unguiculata L. Walp) varieties: Effect of micronisation on physicochemical and structural characteristics. Journal of the Science of Food and Agriculture, 86:35-45.

Mwangwela, A., (2000). Relation of phytic acid, calcium and processing water to culinary characteristics of freshly harvested dry beans. MSc Thesis. University of Malawi, Bunda College.

Ngwira M.M. and Mwangwela A.M., (2002). Culinary Characteristics of Selected Bean Varieties in Malawi Bean/Cowpea Collaborative Research Support Program œ East Africa Proceedings: Bean Seed Workshop. Arusha, Tanzania January 12-14. http://eastafricacrsp.wsu.edu/ 22/02/06.

Penicella, L., (2010). *Influence of Seed coat and Cotyledon Structure on cooking characteristics of cowpeas*, MSc Thesis. University of Pretoria, Pretoriat: <http://hdl.handle.net/2263/25934>

Scott, J. and Maiden, M.1998. Socio-economic survey of three bean-growing areas in Malawi. Occasional paper series No. 24, CIAT, Kampala, Uganda.

Sefa-Dedeh, S., Stanley, D.W. and Voise, P.W. (1979). Effect of storage time and conditions on the Hard-to-cook defect in cowpeas (Vigna unguiculata). Food Science 44, 790-796.

Sefa-Dedeh., S. and Stanley, D.W. 1979b. The relationship of microstructure of cowpeas to water absorption and dehulling properties. Cereal Chemistry 56, 379-386.

Taiwo, K.A., (1998). The potential of cowpea as human food in Nigeria. *Technovation* 18(5/6): 469-481. [DOI: 10.1016/S0166-49](http://doi.org/10.1016/S0166-49).

Wu, X., (2002). Correlation of physio-chemical characteristics in the seed coat and canning quality in different dark red kidney beans (Phaseolus Vulgaris L.) cultivars. MSc Thesis. University of Wisconsin-Stout.